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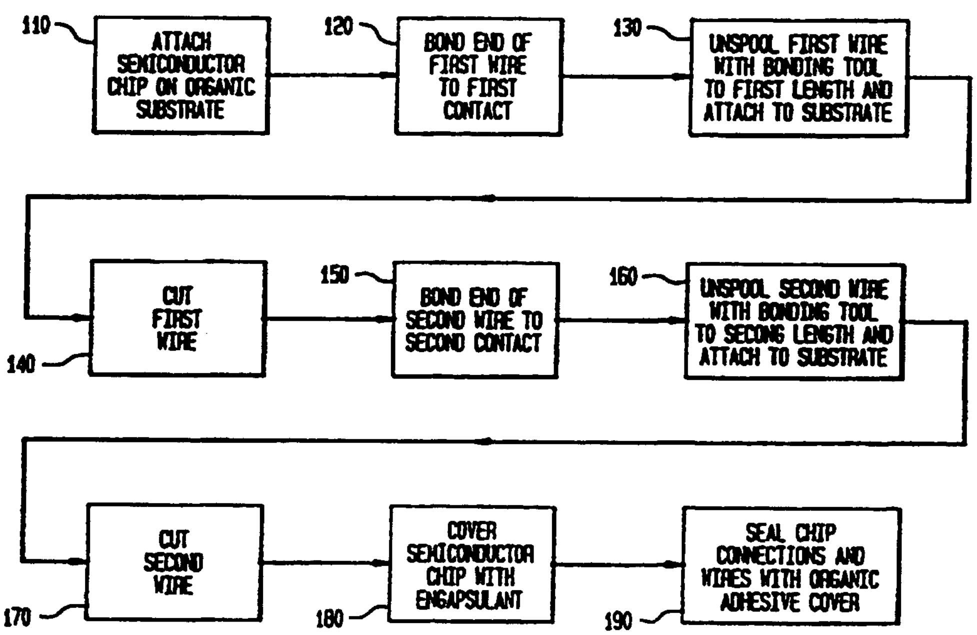


(57) Abstract

A radio frequency tag and its antenna structure are manufactured using wire bonding. A semiconductor chip is placed and attached upon an organic film substrate. The antenna consisting of one or more thin wires is created on the substrate and connected to contacts on the chip using a wire bonding machine. Alternate embodiments using a plurality of semiconductors on a strip of substrate are also disclosed. The chip may be protected with encapsulant and the chip and antenna combination may be sealed between layers of organic film.

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# DESCRIPTION

## METHOD OF MAKING RADIO FREQUENCY IDENTIFICATION TAGS

### FIELD OF THE INVENTION

This invention relates to the field of radio frequency (RF) tagging. More specifically, the invention relates to a method of making an improved small size, low cost RF tag that transmits multiple bits of information.

### BACKGROUND OF THE INVENTION

In general, circuitry is manufactured on hard printed circuit boards or flexible substrates. Printed circuit boards include materials like epoxy-resin or epoxy-glass boards. One generic class on which these circuits are manufactured is FR4. Alternative flexible substrates, also called "flex", include structures of copper on polyimide. These circuits are generally used in automobiles, consumer electronics, and general interconnections.

A well-known technology for attaching to contacts on semiconductor circuits, or "chips", located on the circuit board or flex structure is called wirebonding. Wire bonds are made from small diameter wires (approximately 25 microns in diameter) and with wires that are very short. Generally the wires connected by wire bonds are on the order of 1 millimeter (mm) in length. These wire lengths are normally kept short for several reasons:

1. The small diameter of the wire makes it very weak.

2. In typical circuits many bonds are made and longer lengths would make the connections more prone to electrical shorting.

3. Longer lengths of the wires increase self and mutual inductance which degrade the electrical performance of the circuit.

Radio Frequency Identification (RF ID) is just one of many identification technologies for identifying objects. The heart of the RF ID system lies in an information carrying tag. The tag functions in response to a coded RF signal received from a base station. The tag reflects the incident RF carrier back to the base station. Information is transferred as the reflected signal is modulated bythe tag according to its programmed information protocol.

The tag consists of a semiconductor chip having RF circuits, logic, and memory. The tag also has an antenna, often a collection of discrete components, capacitors and diodes, for example, a battery in the case of active tags, a substrate for mounting the components, interconnections between components, and a means of physical enclosure. One variety of tag, passive tags, has no battery. They derive their energy from the RF signal used to interrogate the tag. In general, RF ID tags are manufactured by mounting the individual elements to a circuit card. This is done by using either short wire bond connections or soldered connections between the board and the circuit elements: chip, capacitors, diodes, antenna. The circuit card may be of epoxy-fiberglass composition or ceramic. The antennas are generally loops of wire soldered to the circuit card or consist of metal etched or plated on a circuit card. The whole assembly may be enclosed in a plastic box or molded into a three-dimensional plastic package.

While the application of RF ID technology is not as widespread as other ID technologies, barcode for example, RF ID is on its way to becoming a pervasive technology in some areas, notably vehicle identification.

Growth in RF ID has been inhibited by the absence of infrastructure for manufacturing the tags, the high cost of tags, the bulkiness of most of the tags, problems of tag sensitivity and range, and the need for the simultaneous reading of multiple numbers of tags. A typical tag costs in the $5 to $10 range. Companies have focused on niche applications. Some prior art discloses RF tags used to identify railway boxcars. RF tags are now used in the automatic toll industry, e.g. on thruway and bridge tolls. RF tags are being tested for uses as contactless fare cards for buses. Employee identification badges and security badges have been produced. Animal identification tags are also commercially available as are RF ID systems for tracking components in manufacturing processes.

One limitation of making RF tags made from PC boards or flex is that the flex or boards must be manufactured first. To meet a demand for very high volumes of tags (greater than one hundred million tags), new factories must be built to produce more board or flex. Further, RF tags made from these technologies are too expensive for many applications. For example, bar codes are a technology that is used for identification at a much lower cost than existing RF tagging technology.

## OBJECTS OF THE INVENTION

An object of this invention is an improved method of making a radio frequency identification tag.

An object of this invention is an improved method of making a low cost radio frequency identification tag that is made from currently available materials.

Another object of this invention is an improved method of making a radio frequency identification tag that can be manufactured in very large quantities.

## SUMMARY OF THE INVENTION

The present invention is a method of manufacture for a novel radio frequency (RF) tag that comprises a semiconductor circuit that has logic, memory, and radio frequency circuits. The semiconductor is mounted on a substrate and is capable of receiving an RF signal through an antenna that is electrically connected to the semiconductor through contacts on the semiconductor.

The antenna is novel, has a novel structure, and is constructed by a novel use of wire bonding techniques. The antenna is one or more wires, each connected to the semiconductor connections by one or two wire bonds. (In one preferred embodiment, the antenna is made of a pair or plurality of pairs of wires.)

One preferred wire bonding method spools out a length of wire required by the antenna design and cuts the second end of the wire without making any electrical connection at the second cut end. In alternative preferred embodiments, the second cut end of the wire is held in place by attaching the cut end to the substrate with adhesive or by local heating of the substrate. In this way, the wire bonding method is used to actually create a component of the RF tag circuit (the antenna) rather than to connect two components. The resulting novel antenna structure is a long wire connected to the circuit by a wire bond. Alternative embodiments include making multiple structures from a plurality of semiconductors on a strip of substrate with a wire bonding tool and making folded dipoles with a wire bonding tool. The components of the novel RF tag are then covered in an organic cover that has a novel use in this type of device.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a flow chart showing the steps of the present invention.

Fig. 2 comprising Figures 2A to 2I, is a drawing showing the Radio Frequency (RF) tag in each step of the method shown in Figure 1.

Figure 3 is a drawing comprising Figures 3A to 3E showing the details of various steps of the method.

Figure 4, comprising Figures 4A and 4B, is a drawing of an RF tag that is being made with a metal pad termination at the end of the antenna wires.

Figure 5, comprises Figures 5A and 5B, which are drawings of a continuous strip of RF tags being cut in order to make individual tags by two preferred embodiment of the present process.

Figure 6 shows a side view of a series of tags being cut into individual segments by an array of knife blades.

Figure 7 is a drawing of the fabrication of a loop antenna by using a temporary post to guide the placement of the antenna wire.

Figure 8 is a drawing of the fabrication of a loop antenna by using an embossed stud to guide the placement of the antenna wire.

Figure 9 is a drawing of the fabrication of a loop antenna by using a raised flap to guide the placement of the antenna wire.

Figure 10 shows the lamination of a tag with two loop antennas between organic covers.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 is a flow chart depicting the steps in a preferred embodiment for chip attachment, wire bonding, and package sealing.

In step 110 a semiconductor chip is placed and attached on an organic substrate 210. (See also Figure 2.) In a preferred embodiment the chip 205 is a radio frequency semiconductor chip. Structures like this are described in U.S. Patent Application number 08/303,976 to Brady et al. entitled "Radio Frequency Identification Tag" filed on September 9, 1994 which is herein incorporated by reference in its entirety.

The chip 205 is placed (Figure 2A) on the substrate 210 by a component pick and place machine 202 which is well known in the semiconductor industry. The chip 205 can be attached 110 to the substrate 210 by several preferred methods. First, the chip may be attached 110 with an adhesive. Preferred adhesives include pressure sensitive adhesives such as acrylics, silicones, urethanes, etc. The adhesive is placed on the substrate 110 by an adhesive dispensing machine. Alternatively, a drop of epoxy may be dispensed between the chip 205 and the substrate 210. Another preferred method of attaching the chip 205 is by heating the substrate using a heating tool such as a heat stage 212. The heat stage 212 can be placed in direct contact with the bottom of the substrate 210 that is opposite of the side where the chip is placed. In this way the substrate is heated to cause the substrate to partially reflow and become sticky so that the chip can be attached to the reflowed area. In another preferred embodiment, the chip itself is heated. This can be done by first placing the chip on the substrate and then locally heating the chip which causes the substrate to reflow or melt and attaches the chip. The chip heating can be performed by a laser 206 or other known methods. Adhesive for attaching the chip can also be provided as a layer 211 on

the substrate. Other attaching means known in the art are contemplated.

The chip 205 has at least two electrical contacts that are used for attachment of a radio frequency antenna. The antenna is attached to the contacts (207, 208) and formed in a novel way using wire bonding (Figure 2B). In one preferred antenna structure, a first antenna connection is wire bonded 120 to the first contact using a wire bonding tool. These tools are capable of ultrasonic wedge bonding, ball bonding, laser bonding, laser sonic bonding, thermocompression, soldering, or any combination of these techniques.

In step 130, the wire is unspooled (Figure 2C) after the first connection is made. In this step, more wire is unspooled than in prior art methods because the unspooled wire is actually used to create the antenna component. The lengths of the wire are determined by the resonant antenna frequency.

In this step 130, the wire has to be unspooled at a controlled rate in relation to the rate of travel of the head of the wire bonding tool so as not to place the unspooled wire in tension. This is common practice in the wire bonding industry for short distance of spooled wire, i.e., 1 mm to 3 mm. However, the present invention, requires that this control be over larger distances of wire spooling. In addition, in certain instances the head will be controlled to slow down with respect to the wire feeding so that a curve or loop can be made during the formation of the antenna component. This spooling creates antennas between 10 mm and 1000 mm in length.

In step 140, the second end of the first wire is cut and the cut end of the wire is left unconnected. The cut can be performed by any well known method including knife blade 213 (swedge, guillotine), mechanical chopper, mechanical pincers,

laser, etc. Steps 150, 160, and 170 repeat steps 120, 130, and 140 for a second wire, respectively.

The cut end of the wire can be attached in place in several ways (steps 130 and 160). The cut end of the wire can be held in place on the substrate by a small drop of adhesive 169 placed below the cut end. (See also Figures 2D and 2G). The adhesive 169 is dispensed by nozzle 168. The cut end can also be held in place by locally heating the substrate at the point where the cut end rests so that the substrate becomes sticky and adheres to the cut end. Localized heating of substrates is well known and includes spot application of heat with tools or a laser beam focused 236 at the point of heating. Adhesives are also well know. They include epoxies, silicones, and phenolic-butyral. Note that the wire can be attached (130, 160) prior to or after the cutting (140, 170). If the wire is attached after the cutting, the cut wire end can be temporarily held in place by pressure before attaching it to the substrate.

A further way of attaching the cut end to the substrate involves heating (Figure 2E) the wire (131, 132) so that the cut end heats up the substrate at the point of contact and causes the cut end to be attached to the substrate. The wire can be heated 231 by inductive heating 237, resistive heating 235, laser heating 236, or any other method used for this purpose. Alternatively, a portion of the substrate under the wire can be heated (235-237) so that part or all of the wire becomes embedded in the substrate. This effect can also be accomplished by heating (235-237) the wire and applying pressure 246 to part (or all) of the wire so that part (or all) of the wire (131, 132) becomes embedded in the substrate. This can also be accomplished by heating (Figure 2F) the substrate with a heat stage 212 so that the wire adheres to a softened part of the substrate. Further, the pressure means 246 can be heated, e.g. resistively 235, so

that pressure and heat are applied simultaneously to the wire 131.

Note that by using the steps described above, more than one wire (131 or 132) can be attached to an individual contact (208 or 207), spooled out, attached to the substrate, and cut. These wires can be placed at different angles with respect to one another.

In step 180 of Figure 1, the chip is covered with a protective encapsulant layer, shown in Figure 2H. A dispensing nozzle 281 places a drop of encapsulant 282 on the surface of the chip 205 to form a protective coating 283. The encapsulant may be an epoxy, silicone, or other polymeric material. In a preferred embodiment the encapsulant is opaque to protect light-sensitive circuits on the chip.

In step 190, the completed chip and antenna structure is sealed (Figure 2I) between organic covers 293 (bottom) and 294 (top) through the use of a roll laminator which presses the sandwich between heated rollers 295 and 296. The organic covers consist of a single layer of polyester, polyethylene, or other organic film that may be softened by heating. In a preferred embodiment the film consists of two layers, an inner layer 297 of the copolymer EVA (ethyl vinyl acetate) and an outer layer 298 of polyester. In an alternative embodiment, only one layer, e.g., the top layer 294, need be applied.

Figure 3 shows the details for the placement (Figure 3A) of the wire 331, bonding (Figures 3B and 3C) of the wire, unspooling (Figure 3D) of the wire, and cutting (Figure 3E) of the wire. In Figure 3A the wire 331 is placed on contact pad 307 on semiconductor chip 305 which has been attached to substrate 310. In Figure 3B the wire 331 is bonded to the pad 307 using ultrasonic energy 334. In Figure 3C the wedge bond 333 has been completed and the bonding head 332 is withdrawn

from the surface as wire is spooled out as shown in Figure 3D. In Figure 3E the wire is terminated at the specified length and cut by knife edge 340.

Figure 4 shows an embodiment 400 of the method in which the wires 431 and 432 are terminated at metal pad termination sites 445 and 446. The top view Figure 4A shows the semiconductor chip 405 on organic substrate 410 with the wires 431 and 432 connected to contacts 445 and 446 on the chip. Figure 4B is a side view.

Contacts 445 (and 446) serve to hold the cut ends of the antenna wires 432 (431) in place. The contacts 445 and 446 can be made of gold, silver, aluminum, copper, nickel, or alloys thereof. These can be deposited as thin layers on the substrate or on another material (like silicon or another metal) that is attached to the surface of the substrate. In a preferred embodiment, no connection other than the antenna wire ends is made to the contacts 445 and 446.

Figure 5A shows a continuous strip 500 of semiconductor chips 505, 515, 525, on organic substrate 502 with wires bonded to first and second contacts 507 and 508 on semiconductor chips. The wires 531, 532 are each one-half wavelength long. After the bonding and sealing operations as shown above in Figures 2 and 3, the strip of tags 501 is cut into segments 541, 542, 543 etc. by knife blade 561 at the position shown by the dotted lines 551 and 552. In a preferred embodiment, the knife blade cuts are made half-way between the chips to make the remaining wire segments 533, 534, 535, 536 etc. each one-quarter wavelength long.

Figure 5B shows a continuous strip array 501 of semiconductor chips 550, 560, 570, 580, 590 on organic substrate 502 with wires bonded to first and second contacts 551 and 553, 561 and 563, 571 and 573, 574 and 575, 577 and 578 as well as third and fourth contacts 552 and 554, 562 and 564, 594 and

595, 581 and 583, 591 and 593 on the semiconductor chips, respectively. In a preferred embodiment, the wires 511, 512, 513, and 514 are each one-half wavelength long. After the bonding and sealing operations as shown above in Figures 2 and 3, the strip array of tags 501 is cut into array segments 517, 518, 519, 520, 521, etc. by knife blade 561 at the positions shown by the dotted lines 522, 523, 524 etc. In a preferred embodiment, the knife blade cuts are made half-way between the chips to make the remaining wire segments 556, 565, 566, 576, 567, 568, etc. each one-quarter wavelength long. In another preferred embodiment, the cuts 522, 523, 524, etc. can be made simultaneously by a gang of knife blades 561.

Note that the semiconductor chips (typically 590) will have one wire (typically 593A) that will not be connected to a contact on another semiconductor chip. In these cases, the end of the wire 593A will be terminated in any of the ways describe above. In one preferred embodiment, the wire 593A will be terminated to a contact (typically 593B) located on the substrate as shown in Figure 4. Note further that Figure 5B shows three rows of semiconductor chips forming an array on the substrate. (One row is shown in Figure 5A.) However, the number of rows can vary from two to as many as will fit on the substrate.

Figure 6 shows a strip of RF tags 610 being cut 650 into individual segments 611, 612, 613 by an array of knife blades 641 and 642.

Figure 7 shows the manufacture 700 of a loop antenna through the use of a temporary post wire guide 720. The post 720 is lowered 750 to the substrate 710. After the wire 730 is first bonded to contact pad 207 of Figure 2, the wire is unspooled 130 by the bonding head 740. The wire 730 is guided by the bonding head around the temporary post 720. The process is mirrored at the other end of the substrate and the wire is

bonded to contact pad 208 of Figure 2 to form the loop antenna. The temporary post 720 is then raised 751 to complete the process. The wire is attached to the substrate using methods described above.

Figure 8 shows the manufacture 800 of a loop antenna through the use of an embossed stud 820 wire guide. The stud 820 is permanently embossed in the substrate 810. After the wire 830 is first bonded to contact pad 207 of Figure 2, the wire is unspooled by the bonding head 840. It is guided by the bonding head around the embossed stud 820. The process is mirrored at the other end of the substrate and the wire is bonded to contact pad 208 of Figure 2 to form the loop antenna. The stud 820 remains in place on the substrate.

Figure 9 shows the manufacture 900 of a loop antenna through the use of a raised flap wire guide 920. The flap is pre-punched into the substrate 910 by a punching tool. The flap 920 is then raised in the substrate 910 by mechanical methods such as an air jet 925 or pin 926. After the wire 930 is first bonded to contact pad 207 of Figure 2, the wire is unspooled by the bonding head 940. It is guided by the bonding head around the raised flap 920. The process is mirrored at the other end of the substrate and the wire is bonded to contact pad 208 of Figure 2 to form the loop antenna. The mechanical raising means 925 is removed, the flap 920 relaxes, and the flap 920 holds the wire 930 in place on the substrate.

Note that in some preferred embodiments of the methods illustrated in Figures 7-9, the wire can be attached to the substrate by any of the methods described above, e.g., heat and/or pressure.

Figure 10 shows the completion of a tag 1000 by means of the application of heat 1064 and pressure 1065. Multiple antennas 1020 (and 1030) have been created by the bonding of

wire 1025 (and 1035) to contact pads 1006 and 1008 (1007 and 1009), on semiconductor chip 1010. Encapsulant 1030 has been dispensed to cover the chip 1005 and contact pads (1006-1009). The substrate 1040 is placed below organic cover 1045. In a preferred embodiment, the organic cover consists of an outer layer of PET 1060 and an inner layer of EVA 1050. Heat 1064 and pressure 1065 are applied to seal the package. In another embodiment, a bottom cover 1046 is place below the tag and is laminated simultaneously with top cover 1045. PET is also known as polyester.

Given this disclosure, one skilled in the art come develop equivalent embodiments of this invention that are within the contemplation of the inventors. For example, the methods described in Figure 2, 3, and 5 can be used to create radio frequency tags each with multiple antennas that are at different angles (e.g. non-orthogonal) to one another.

## DEFINITIONS

1. A method for making a radio frequency tag comprising the steps of:

   a. attaching a semiconductor on an organic substrate, the semiconductor having a first and second contact, memory and logic to modulate a radio frequency signal with a frequency;

   b. attaching a bonded end of a first wire to the first contact using a wire bonding machine;

   c. spooling the first wire with the wire bonding machine to a first length;

   d. attaching the first wire to the organic substrate;

   e. cutting the wire at the first length at a first cut end;

   f. attaching a bonded end of a second wire to the second contact using a wire bonding machine;

   g. spooling the second wire with the wire bonding machine to a second length;

   h. attaching the second cut wire to the organic substrate; and

   j. cutting the second wire at the second length at a second cut end;

   whereby the first and second wire form an antenna that receives a signal at the frequency, the signal being modulated by the semiconductor logic and the modulated signal being transmitted by the antenna.

2. A method, as in claim 1, where the first and second length are equal to one quarter wavelength of the frequency.

3. A method, as in claim 1, comprising a further step of encapsulating the semiconductor and the first and second contact with an encapsulant.

4. A method, as in claim 3, where the encapsulant is any encapsulant including epoxy, silicone, or polymeric material.

5. A method, as in claim 1, where the semiconductor is attached to the substrate with a chip-attaching adhesive.

6. A method, as in claim 5, where the chip-attaching adhesive is any adhesive including acrylics, silicones, and urethanes.

7. A method, as in claim 1, where the semiconductor is attached to the substrate by heating the substrate.

8. A method, as in claim 1, where the semiconductor is attached to the substrate by heating the semiconductor.

9. A method, as in claim 1, where the wires are attached to the substrate by a wire-attaching adhesive.

10. A method, as in claim 9, where the wire-attaching adhesive is any adhesive including epoxies, silicones, and phenolic-butyral.

11. A method, as in claim 1, where the wires are attached to the substrate by heating the substrate.

12. A method, as in claim 1, where the wires are attached to the substrate by heating the wires.

13. A method, as in claim 1, comprising a further step of sealing the substrate, semiconductor, and first and second wires with a top organic cover.

14. A method, as in claim 13, where the top organic cover is a single layer.

15. A method, as in claim 14, where the top organic cover is made of any organic film including polyester and polyethylene and is attached to the substrate, semiconductor and wires by heating.

16. A method, as in claim 13, where the top organic cover has an outer and inner layer, the outer layer being an organic film and the inner layer being a cover adhesive.

17. A method, as in claim 16, where the cover adhesive is sensitive and the cover is attached to the substrate, semiconductor and wires by heating.

18. A method, as in claim 17, where pressure is also added to attach the cover.

19. A method, as in claim 17, where the cover adhesive is a copolymer including ethyl vinyl acetate (EVA).

20. A method, as in claim 16, where the cover adhesive is pressure sensitive and the cover is attached to the substrate, semiconductor and wires by pressure.

21. A method, as in claim 20, where the cover adhesive is an adhesive including acrylics, silicones, and urethanes.

22. A method, as in claim 1, where the top of the substrate is covered by an attached top cover and the bottom of the substrate is covered by an attached bottom cover.

23. A method for making a radio frequency tag comprising the steps of:

    a. attaching a semiconductor on an organic substrate, the semiconductor having a first and second chip contact, memory and logic to modulate a radio frequency signal with a frequency;

    b. attaching a first bonded end of a first wire to the first chip contact using a wire bonding machine;

    c. spooling the first wire with the wire bonding machine to a first length;

    d. attaching a first cut end of the first wire to a first termination site on the substrate;

    e. cutting the wire at the first length at the first cut end;

    f. attaching a second bonded end of a second wire to the second contact using a wire bonding machine;

    g. spooling the second wire with the wire bonding machine to a second length;

    h. attaching a second cut end of the second wire to a second termination site on the substrate; and

    i. cutting the second wire at the second length at a second cut end, whereby the first and second wire form a antenna that receives a signal at the frequency, the signal being modulated by the

semiconductor logic and the modulated signal being transmitted by the antenna.

24. A method, as in claim 23, where the first and second length are equal to one quarter wavelength of the frequency.

25. A method for making a radio frequency tag comprising the steps of:

a. attaching three or more semiconductors on a strip of organic substrate, each semiconductor having a first and second chip contact, memory and logic to modulate a radio frequency signal with a frequency;

b. attaching a first bonded end of a first wire to the first chip contact on a first chip using a wire bonding machine;

c. spooling the first wire with the wire bonding machine to a first length;

d. attaching a first cut end of the first wire to a second chip contact on a second chip using a wire bonding machine;

e. cutting the wire at the first length at the first cut end;

f. attaching a second bonded end of a second wire to the second contact of the first chip using a wire bonding machine;

g. spooling the second wire with the wire bonding machine to a second length;

h. attaching a second cut end of the second wire to a first chip contact on a third chip using a wire bonding machine;

i. cutting the second wire at the second length at the second cut end; and

j. cutting the first wire between the first and second semiconductor and cutting the second wire between the first and third semiconductor,

whereby the first and second wire form a antenna that receives a signal at the frequency, the signal being modulated by the semiconductor logic and the modulated signal being transmitted by the antenna.

26. A method for making a radio frequency tag comprising the steps of:

a. attaching a semiconductor on an organic substrate, the semiconductor having a first and second contact, memory and logic to modulate a radio frequency signal with a frequency;

b. attaching a first bonded end of a wire to the first contact on the semiconductor using a wire bonding machine;

c. spooling the first wire with the wire bonding machine around one or more wire guides;

d. attaching the cut end of the wire to the second contact using a wire bonding machine; and

e. cutting the wire at a length at a cut end located at the second contact,

whereby the wire forms a folded dipole antenna that receives a signal at the frequency, the signal being modulated by the semiconductor logic and the modulated signal being transmitted by the antenna.

27. A method, as in claim 26, where the semiconductor has two or more pairs of first and second contacts and steps a - e are repeated for each pair of contacts to create more than one folded dipole antenna.

28. A method, as in claim 26, where one or more guides is a stud embossed in the substrate.

29. A method, as in claim 26, where one or more guides is a temporary post temporarily in contact with the substrate.

30. A method, as in claim 29, where the wire is attached to the substrate by heat.

31. A method, as in claim 26, where one or more guides is a flap punched in the substrate.

32. A method, as in claim 31, where the flap is raised by an air jet in order to capture the wire being looped by the wire bonding machine.

33. A method, as in claim 31, where the flap is raised by a pin.

34. A method for making a plurality radio frequency tags comprising the steps of:

   a. attaching four or more semiconductors on a strip of organic substrate in an array, each semiconductor having a first, second, third, and fourth chip

contact, and a memory and a logic to modulate a radio frequency signal with a frequency;

b. attaching a first bonded end of a first wire to the first chip contact on a first chip using a wire bonding machine;

c. spooling the first wire with the wire bonding machine to a first length;

d. attaching a first cut end of the first wire to a second chip contact on a second chip using a wire bonding machine;

e. cutting the wire at the first length at the first cut end;

f. attaching a second bonded end of a second wire to the second contact of the first chip using the wire bonding machine;

g. spooling the second wire with the wire bonding machine to a second length;

h. attaching a second cut end of the second wire to a first chip contact on a third chip using the wire bonding machine;

i. cutting the second wire at the second length at the second cut end;

j. attaching a third bonded end of a third wire to the third chip contact on the first chip using the wire bonding machine;

k. spooling the third wire with the wire bonding machine to a third length;

l. attaching a third cut end of the third wire to a fourth chip contact on a fourth chip using the wire bonding machine;

m. cutting the third wire at the third length at the third cut end;

n. attaching a fourth bonded end of a fourth wire to the fourth chip contact on the first chip using the wire bonding machine;

o. spooling the fourth wire with the wire bonding machine to a fourth length;

p. attaching a fourth cut end of the fourth wire to a connection contact on the substrate;

q. cutting the fourth wire at the fourth length at the fourth cut end;

r. cutting the first wire between the first and second semiconductor, cutting the second wire between the first and third semiconductor, and cutting the third wire between the first and fourth semiconductor,

whereby the first, second, third, and fourth wires form two antennas that receive a signal at the frequency, the signal being modulated by the semiconductor logic and the modulated signal being transmitted by the antenna.

35. A method, as in claim 34, where the connection contact is a contact on a fifth semiconductor and the fourth wire is cut between the first and fifth semiconductor.

36. A method, as in claim 34, where the two antennas each have two wire elements of equal length.

## CLAIMS

1. A method for making a radio frequency tag comprising the steps of:

   a. attaching a semiconductor on an organic substrate, the semiconductor having a first and second contact, memory and logic to modulate a radio frequency signal with a frequency;

   b. attaching a bonded end of a first wire to the first contact using a wire bonding machine;

   c. spooling the first wire with the wire bonding machine to a first length;

   d. attaching the first wire to the organic substrate;

   e. cutting the wire at the first length at a first cut end;

   f. attaching a bonded end of a second wire to the second contact using a wire bonding machine;

   g. spooling the second wire with the wire bonding machine to a second length;

   h. attaching the second cut wire to the organic substrate; and

   j. cutting the second wire at the second length at a second cut end;

   whereby the first and second wire form an antenna that receives a signal at the frequency, the signal being modulated by the semiconductor logic and the modulated signal being transmitted by the antenna.

2. A method, as in claim 1, where the first and second length are equal to one quarter wavelength of the frequency.

3. A method, as in claim 1, comprising a further step of encapsulating the semiconductor and the first and second contact with an encapsulant.

4. A method, as in claim 3, where the encapsulant is any encapsulant including epoxy, silicone, or polymeric material.

5. A method, as in claim 1, where the semiconductor is attached to the substrate with a chip-attaching adhesive.

6. A method for making a radio frequency tag comprising the steps of:

   a. attaching a semiconductor on an organic substrate, the semiconductor having a first and second chip contact, memory and logic to modulate a radio frequency signal with a frequency;

   b. attaching a first bonded end of a first wire to the first chip contact using a wire bonding machine;

   c. spooling the first wire with the wire bonding machine to a first length;

   d. attaching a first cut end of the first wire to a first termination site on the substrate;

   e. cutting the wire at the first length at the first cut end;

f. attaching a second bonded end of a second wire to the second contact using a wire bonding machine;

g. spooling the second wire with the wire bonding machine to a second length;

h. attaching a second cut end of the second wire to a second termination site on the substrate; and

i. cutting the second wire at the second length at a second cut end, whereby the first and second wire form a antenna that receives a signal at the frequency, the signal being modulated by the semiconductor logic and the modulated signal being transmitted by the antenna.

7. A method for making a radio frequency tag comprising the steps of:

a. attaching three or more semiconductors on a strip of organic substrate, each semiconductor having a first and second chip contact, memory and logic to modulate a radio frequency signal with a frequency;

b. attaching a first bonded end of a first wire to the first chip contact on a first chip using a wire bonding machine;

c. spooling the first wire with the wire bonding machine to a first length;

d. attaching a first cut end of the first wire to a second chip contact on a second chip using a wire bonding machine;

e. cutting the wire at the first length at the first cut end;

f. attaching a second bonded end of a second wire to the second contact of the first chip using a wire bonding machine;

g. spooling the second wire with the wire bonding machine to a second length;

h. attaching a second cut end of the second wire to a first chip contact on a third chip using a wire bonding machine;

i. cutting the second wire at the second length at the second cut end; and

j. cutting the first wire between the first and second semiconductor and cutting the second wire between the first and third semiconductor,

whereby the first and second wire form a antenna that receives a signal at the frequency, the signal being modulated by the semiconductor logic and the modulated signal being transmitted by the antenna.

8. A method for making a radio frequency tag comprising the steps of:

a. attaching a semiconductor on an organic substrate, the semiconductor having a first and second contact, memory and logic to modulate a radio frequency signal with a frequency;

b. attaching a first bonded end of a wire to the first contact on the semiconductor using a wire bonding machine;

c. spooling the first wire with the wire bonding machine around one or more wire guides;

d. attaching the cut end of the wire to the second contact using a wire bonding machine; and

e. cutting the wire at a length at a cut end located at the second contact,

whereby the wire forms a folded dipole antenna that receives a signal at the frequency, the signal being modulated by the semiconductor logic and the modulated signal being transmitted by the antenna.

9. A method for making a plurality radio frequency tags comprising the steps of:

a. attaching four or more semiconductors on a strip of organic substrate in an array, each semiconductor having a first, second, third, and fourth chip contact, and a memory and a logic to modulate a radio frequency signal with a frequency;

b. attaching a first bonded end of a first wire to the first chip contact on a first chip using a wire bonding machine;

c. spooling the first wire with the wire bonding machine to a first length;

d. attaching a first cut end of the first wire to a second chip contact on a second chip using a wire bonding machine;

e. cutting the wire at the first length at the first cut end;

f. attaching a second bonded end of a second wire to the second contact of the first chip using the wire bonding machine;

g. spooling the second wire with the wire bonding machine to a second length;

h. attaching a second cut end of the second wire to a first chip contact on a third chip using the wire bonding machine;

i. cutting the second wire at the second length at the second cut end;

j. attaching a third bonded end of a third wire to the third chip contact on the first chip using the wire bonding machine;

k. spooling the third wire with the wire bonding machine to a third length;

l. attaching a third cut end of the third wire to a fourth chip contact on a fourth chip using the wire bonding machine;

m. cutting the third wire at the third length at the third cut end;

n. attaching a fourth bonded end of a fourth wire to the fourth chip contact on the first chip using the wire bonding machine;

o. spooling the fourth wire with the wire bonding machine to a fourth length;

p. attaching a fourth cut end of the fourth wire to a connection contact on the substrate;

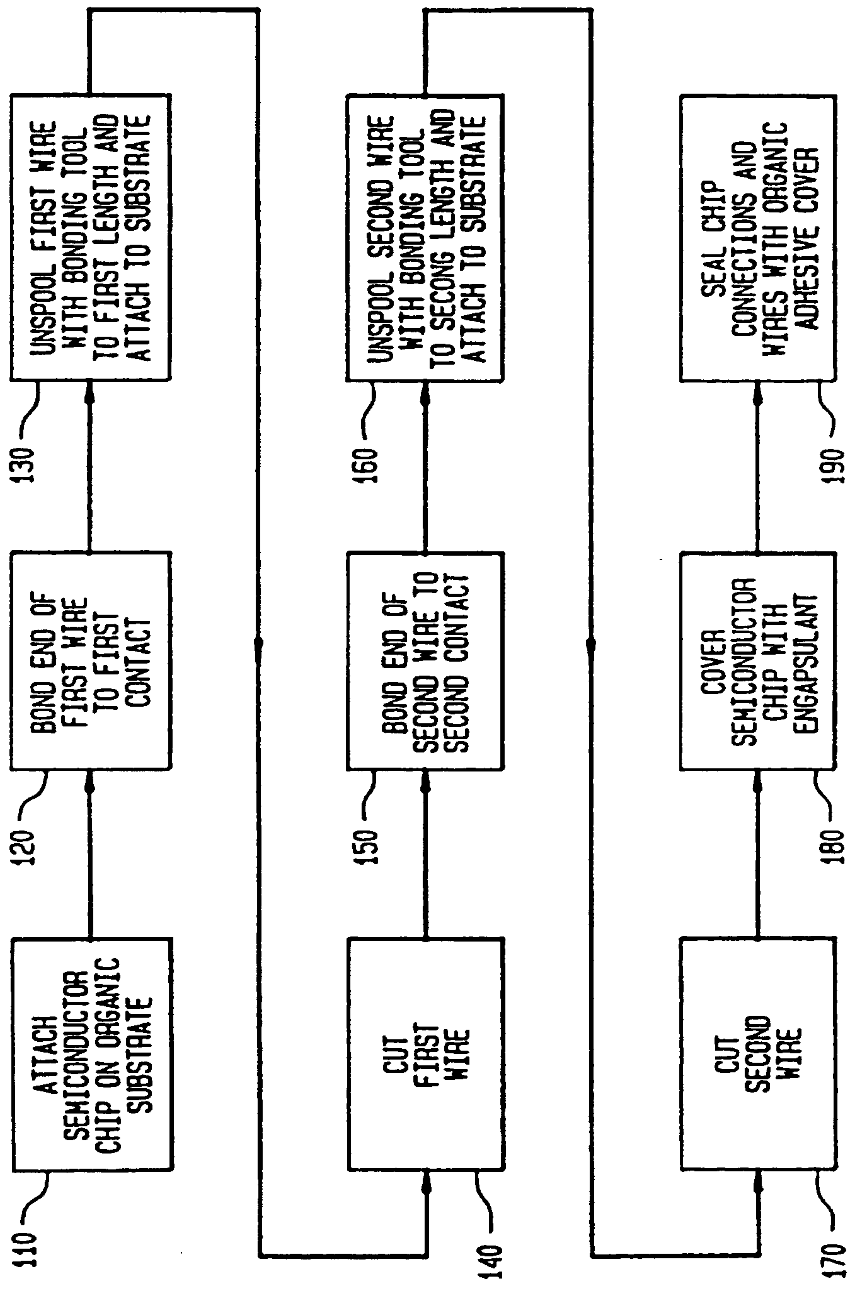
q. cutting the fourth wire at the fourth length at the fourth cut end;

r. cutting the first wire between the first and second semiconductor, cutting the second wire between the first and third semiconductor, and cutting the third wire between the first and fourth semiconductor,

whereby the first, second, third, and fourth wires form two antennas that receive a signal at the frequency, the signal being modulated by the semiconductor logic and the modulated signal being transmitted by the antenna.

10. A radio frequency tag obtainable according to anyone of the preceeding claims.

FIG. 1


110
ATTACH SEMICONDUCTOR CHIP ON ORGANIC SUBSTRATE
120
BOND END OF FIRST WIRE TO FIRST CONTACT
130
UNSPOOL FIRST WIRE WITH BONDING TOOL TO FIRST LENGTH AND ATTACH TO SUBSTRATE
140
CUT FIRST WIRE
150
BOND END OF SECOND WIRE TO SECOND CONTACT
160
UNSPOOL SECOND WIRE WITH BONDING TOOL TO SECONG LENGTH AND ATTACH TO SUBSTRATE
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CUT SECOND WIRE
180
COVER SEMICONDUCTOR CHIP WITH ENCAPSULANT
190
SEAL CHIP CONNECTIONS AND WIRES WITH ORGANIC ADHESIVE COVER

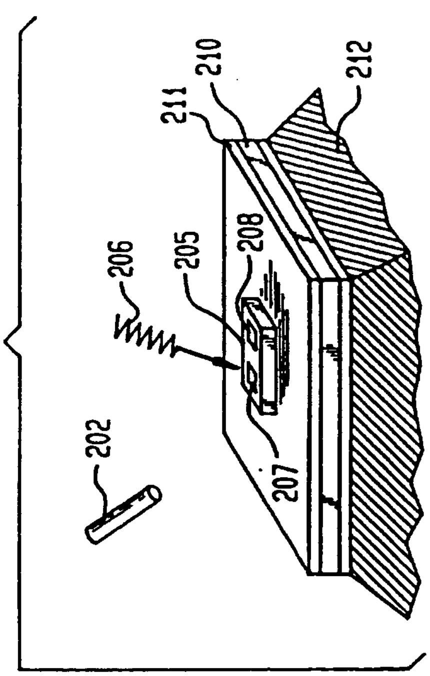



FIG. 2A

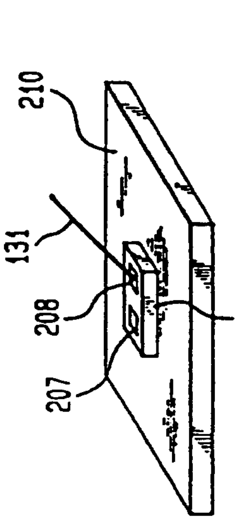



FIG. 2B

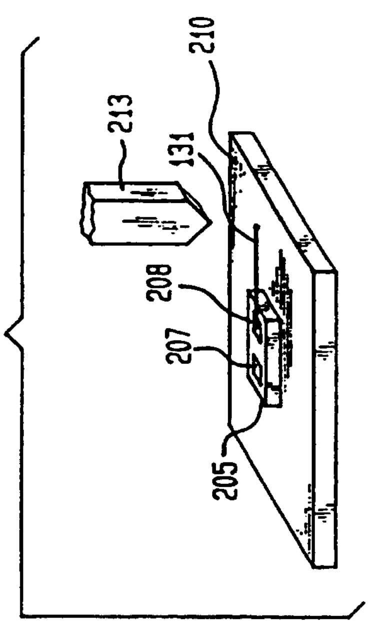



FIG. 2C

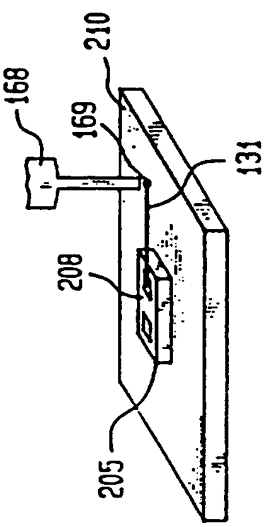



FIG. 2D

FIG. 2E

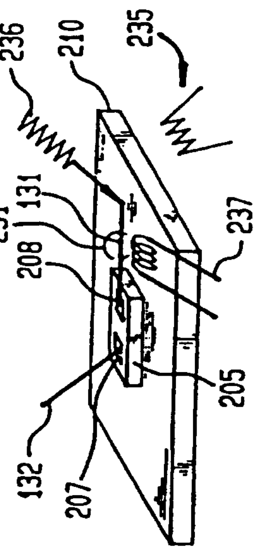



FIG. 2G

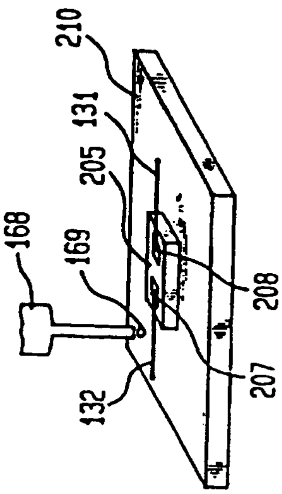
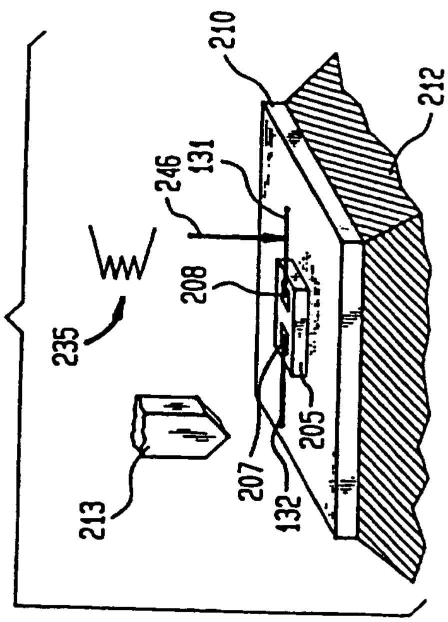



FIG. 2F



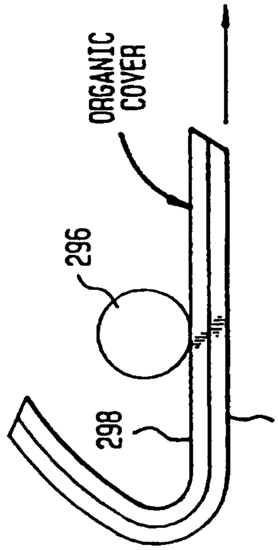



FIG. 2J

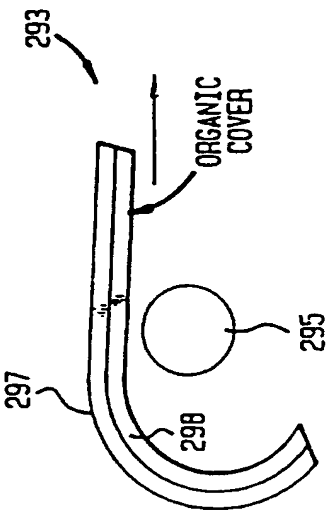



FIG. 2K

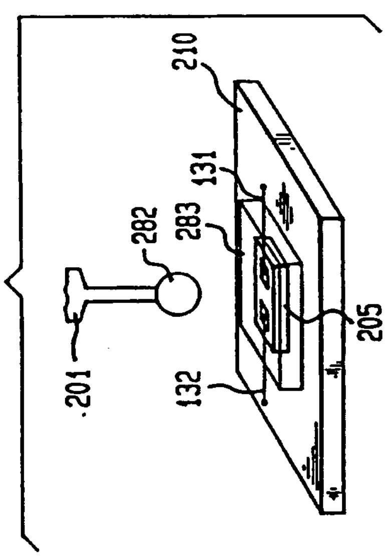



FIG. 2H

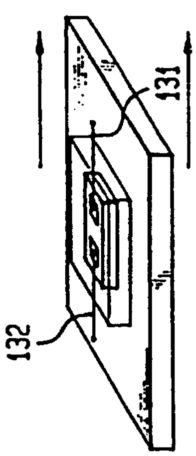



FIG. 2I

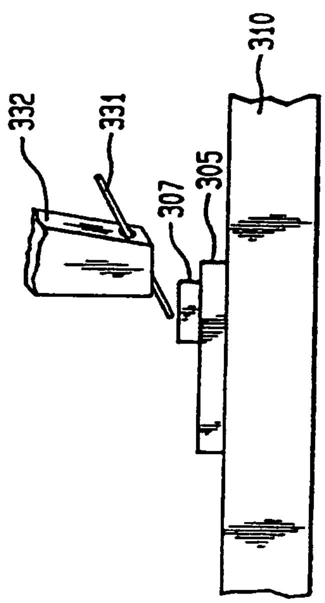



FIG. 3A

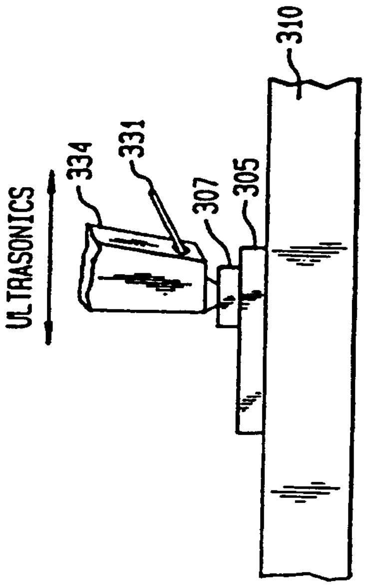



FIG. 3B

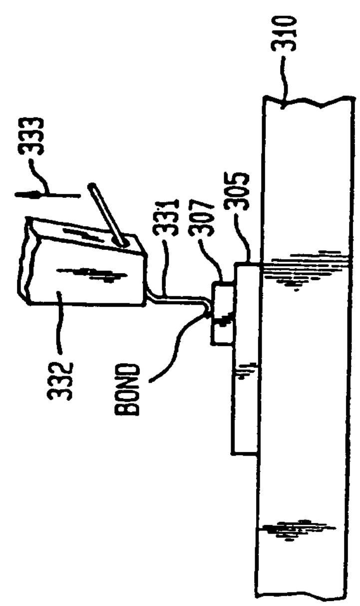



FIG. 3C

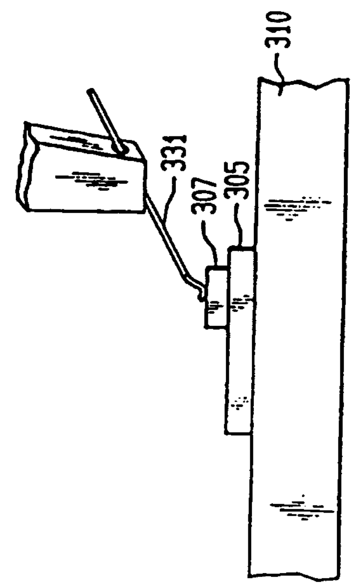



FIG. 3D

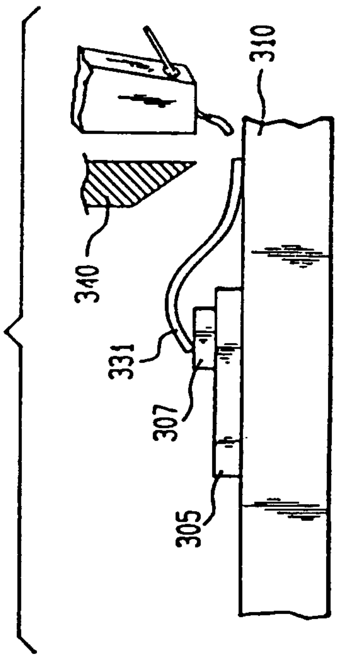



FIG. 3E

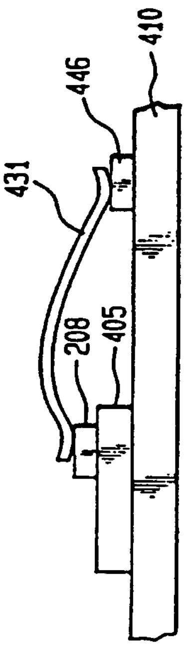



FIG. 4B

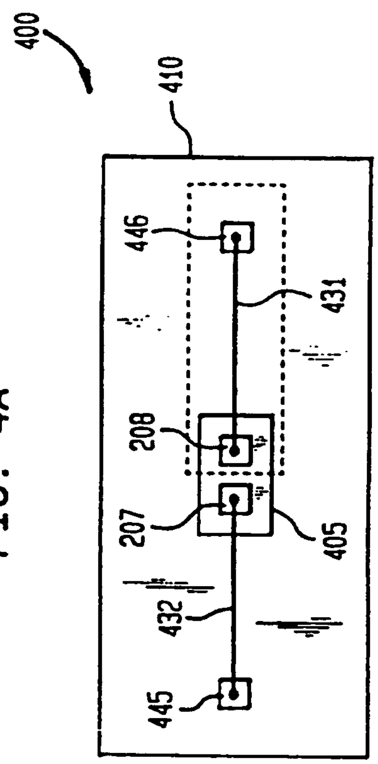



FIG. 4A

FIG. 5A

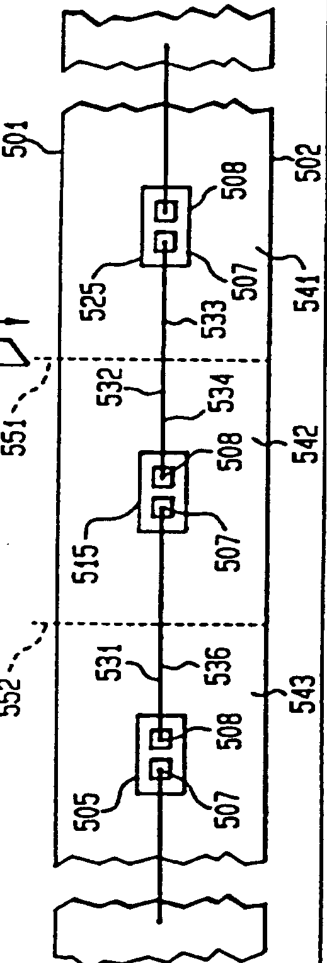

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FIG. 5B

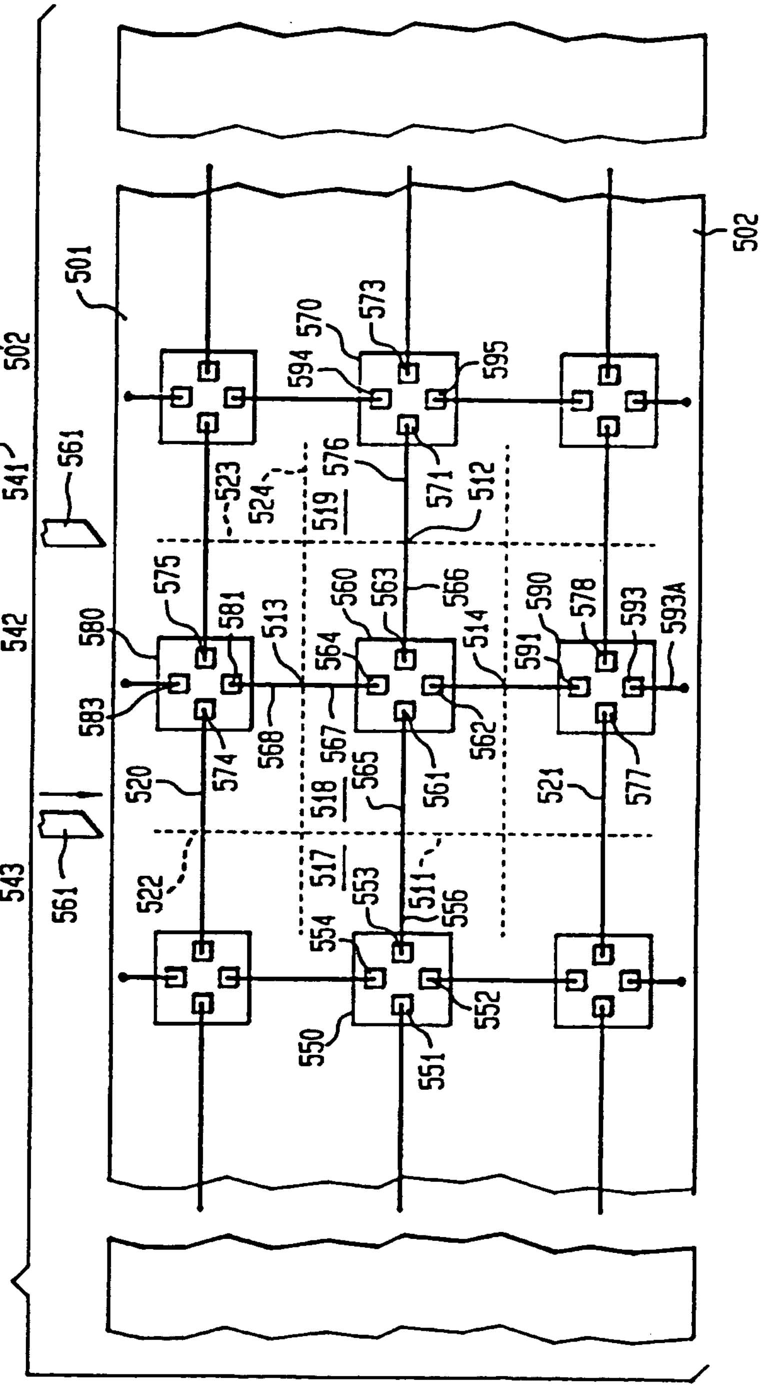
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FIG. 6

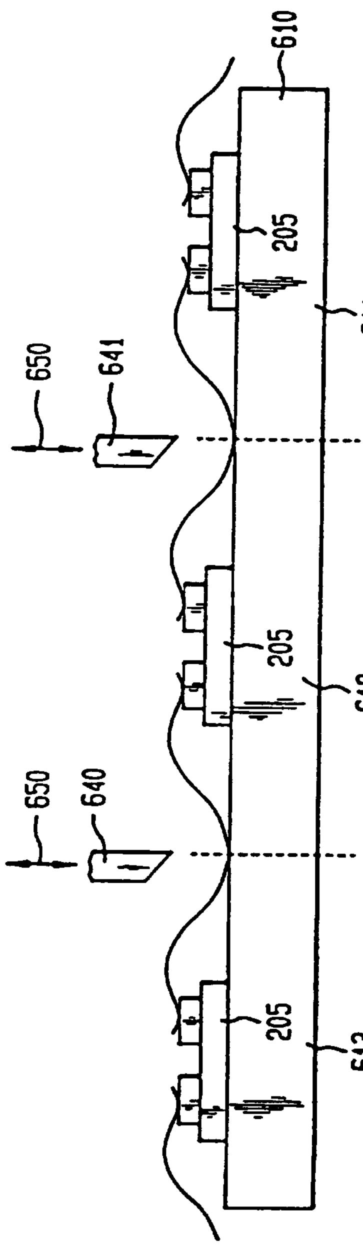
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FIG. 7

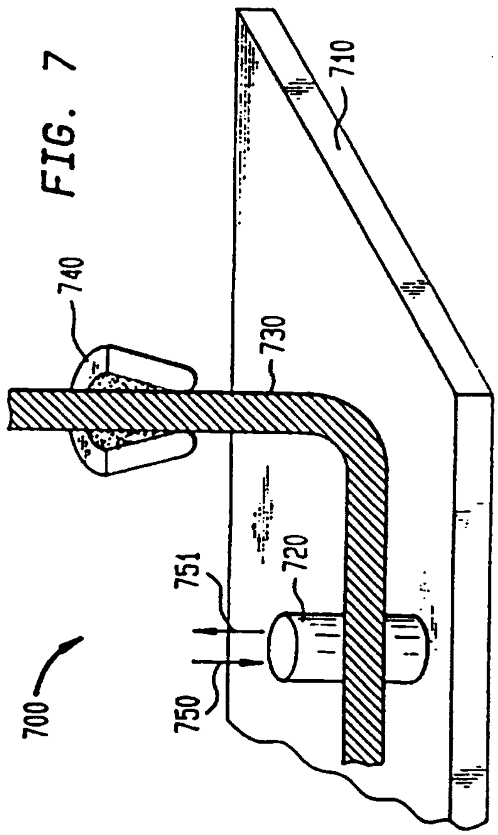
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FIG. 8

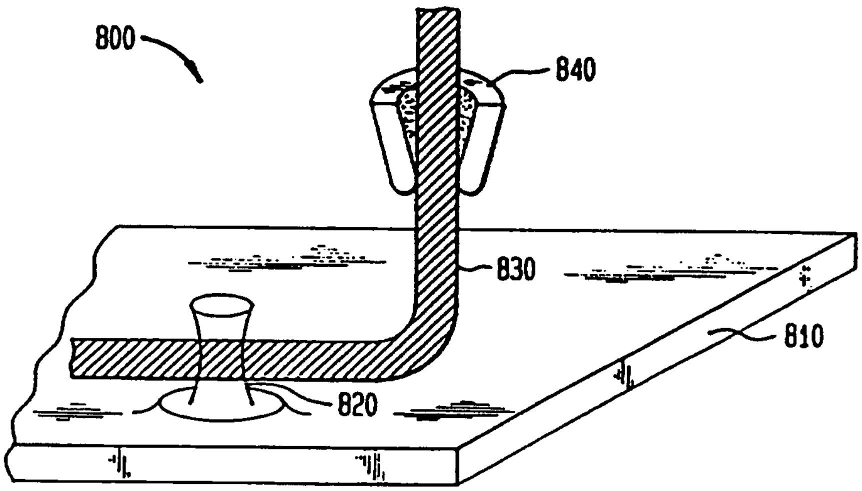



FIG. 9

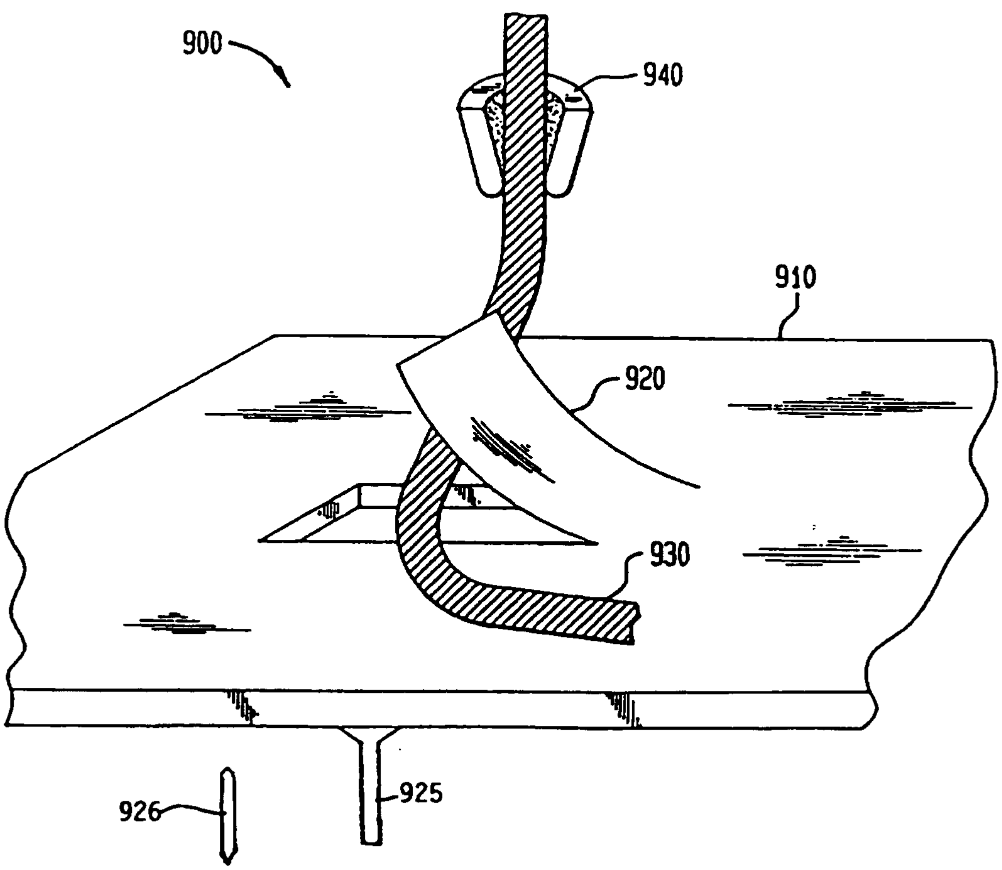
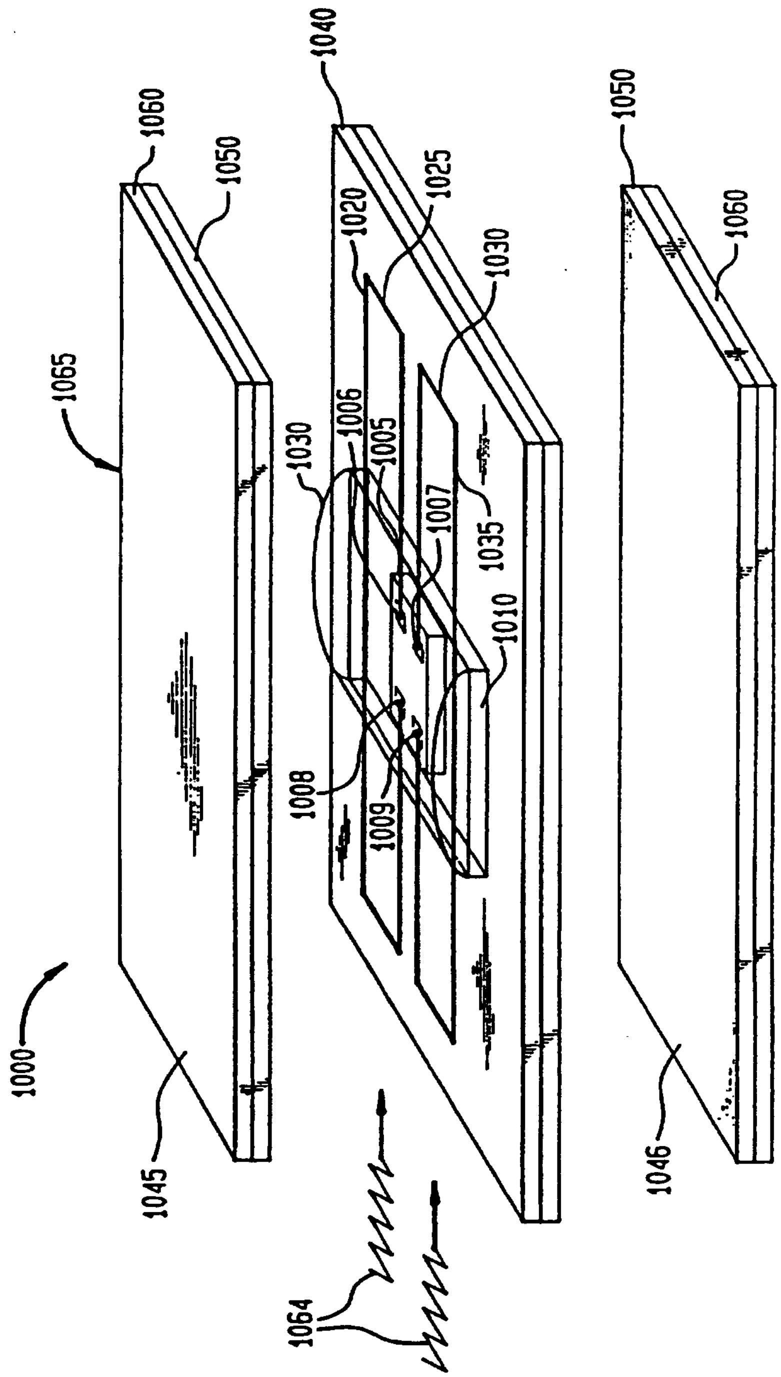


FIG. 10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# INTERNATIONAL SEARCH REPORT

Int. onal Application No
PCT/EP 95/03703

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 6 G06K7/08 G06K19/067

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | WO,A,93 18493 (N.V. NEDERLANDSCHE APPARATENFABRIEK NEDAP) 16 September 1993<br>see the whole document<br>--- | 1,5-7,10 |
| A | DE,A,43 19 878 (MICRON TECHNOLOGY INC.) 23 December 1993<br>see column 10, line 65 - line 68<br>see column 11, line 1 - line 8<br>--- | 1,2,5,8,<br>10 |
| A | GB,A,1 461 986 (CENTRAL GLASS CO. LTD) 19 January 1977<br>see the whole document<br>----- | 1,6,8,9 |

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

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"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 17 January 1996 | 30. 01. 96 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Herskovic, M |

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 95/03703

| Patent document cited in search report | Publication date | Patent family member(s) | | Publication date |
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| GB-A-1461986 | 19-01-77 | JP-C- | 1011845 | 29-08-80 |
| | | JP-A- | 50140861 | 12-11-75 |
| | | JP-B- | 55002905 | 22-01-80 |
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| | | FR-A,B | 2269409 | 28-11-75 |
| | | US-A- | 4196038 | 01-04-80 |